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APPENDIX B
DESIGN CALCULATIONS

1.0 INTRODUCTION.

This appendix presents a description of the general types of calculations that may be required for filter press applications. Based on the specific type of sludge being dewatered, sludge dewatering conditions, and the specific type of equipment and accessories used, additional calculations may be required. Although the calculations that are described refer primarily to filter press applications, several of these calculations are dependent on, or should be used in conjunction with, other calculations that should be performed or used in the development of the design for the entire treatment process or treatment facility. Design examples illustrating the use of several of these calculations are presented in Appendix E.

2.0 PURPOSE.

The primary purpose of the filter press design calculations is to provide design criteria for sizing equipment for editing guide specifications and developing construction drawings. Based on the preliminary selection of equipment, additional calculations can also be performed to determine parameters such as utility requirements and supporting mechanical and electrical distribution systems.

3.0 DESIGN BASIS AND DATA SOURCES.

Several types of data sources can be used for the basis of the design calculations. Typical sources of data include pre-engineering design reports and treatability studies, standard reference materials, and other sources such as telephone conversations. Any source of data or basis used for the design calculations should be identified and referenced appropriately in the design analysis.

3.1 PRE-ENGINEERING DESIGN AND TREATABILITY STUDIES.

Pre-engineering design reports and treatability studies (i.e., laboratory, bench—scale and/or pilot scale testing) are typically used as the basis of the design calculations. Prior to performing the filter press design calculations, the following specific parameters should be identified, if possible, from these sources:

- Sludge flow rates and solids concentration from each process generating sludge.

- A representative and/or composite density or specific gravity of the wet sludge feed stream(s).
- A determination of sludge conditioning chemical dosages required, usually based on a weight percent of dried sludge solids.
- Minimum dry solids allowed in the cake by weight percent of wet sludge feed.
- A representative and/or composite density or specific gravity of the wet sludge cake.
- A determination of the sludge cake thickness.
- A determination of the filtrate solids content.
- A determination of operating time (i.e., 8 hour/day).
- Total cycle time which includes all time required for sludge filtration, cake discharge, and all other related time requirements (i.e., core blow).

Each data source used should be clearly identified within the design calculation and properly referenced with the date, title, or other pertinent information that will identify the data source and its validity.

3.2 REFERENCES MATERIALS.

Data and information from reference materials, other than data from pre-engineering design and treatability studies, can be also used for filter press design calculations. Reference materials consist of applicable codes, standards, textbooks, standard tables, and manufacturers catalogs and examples of manufacturers literature. Each reference source used should be properly referenced with the date, title, issue, or other pertinent information to assure complete identification.

3.3 TELEPHONE CONVERSATIONS RECORDS.

In addition to reference and design data from the design analysis report, telephone conversations to equipment suppliers and manufacturers and regulatory agencies may also be used for the design calculations.

4.0 COMPOSITION/CONCENTRATION DEPENDENT CALCULATIONS.

Composition and concentration calculations are performed to provide the design basis for sizing the filter press equipment and for related operation requirements. These types of calculations can be categorized as pretreatment calculations and process calculations.

4.1 PRETREATMENT CALCULATIONS.

Pretreatment calculations include those that are required to provide the initial basis for sizing equipment and process conditions such as mass balance calculations and determination of the required filter press volume.

4.1.1 Mass Balance Calculations.

The mass balance calculations should be performed based on previously determined hydraulic flow rates and solids concentrations for each sludge generating stream to determine the total mass flow rate of sludge to be dewatered. This calculation is based on the mass balance equation:

Mass Out = Mass In.

The “mass out” term refers to the total solids to be removed by dewatering. This term is determined from the “mass in” term, that is determined by the summation of mass flow rates from each sludge generating unit as determined from multiplying the sludge flow rate by solids concentration from each unit. The sludge generating units may consist of clarifiers, biological treatment units, etc. To aid in these calculations, a flow schematic showing both hydraulic flow rates, solid concentrations, and mass flow rates to and from each process unit should be developed.

Based on the calculation of total mass of sludge generated on a daily basis, other process calculations can be performed to determine the filter press volume and related sludge storage, chemical feed systems, and other filter press accessories.

4.1.2 Filter Press Volume.

Based on the calculation of the “mass out” term of the mass balance equation the volumetric filter press capacity can be determined by the following equation:

Cake volume produced per day =

[(weight sludge dried solids per day) x
(1 + fraction of conditioning chemical(s))] /

[(% cake solids content) x (wet sludge cake density)]

Based on this volumetric calculation and the previously determined parameters, the filter press can be sized based on the following calculation:

Filter press volume capacity per cycle =

[(cake volume produced per day) x
(hour per cycle)) / [operating period (hour per day))]

Based on this capacity, a filter press should be selected from manufacturer*s information. The filter press selected and the accessories required can then be used in the determination of utility requirements and subsequent sizing of other equipment.

4.2 PROCESS CALCULATIONS.

Process calculations include these related to the determinations of design criteria and sizing of storage containers, chemical feed systems, and accessories.

4.2.1 Storage Calculations.

Several types of storage containers may be required for filter press applications including tanks for storage of sludge, sludge conditioning, filter precoat, filter media wash, acid wash, and sludge cake storage.

In general the sizing of these storage containers is either based on the amount of detention required, and/or the frequency, duration, and quantity of material required for the normal filter press operation.

4.2.1.1 Sludge Storage.

The amount of storage required for the raw sludge is very site specific and/or dependent on requirements of equalizing flow and sludge characteristics, in addition to considerations of retention in treatment process tank. A general rule provided by the “Ten States Standards” is that a minimum of four days storage shall be provided for mechanical dewatering facilities unless other standby wet sludge facilities are available (GLUMRB 1990). In general, the sludge storage capacity can be calculated by the following equation:

Sludge Storage Volume Requirement =

(Volume of Sludge Produced Per Day) x (Number of Days Required for Storage)

4.2.1.2 Sludge Conditioning Storage.

The sludge conditioning tank size will be based on the amount of sludge to be processed and the conditioning chemicals required. In general, the tanks used for this application will be vertical, cylindrical tanks equipped with a mixer and high and lower level indication. Based on the quantities of sludge and conditioning chemicals required, a working volume should be calculated by the following equation:

Working Volume of Tank Per Cycle =

(Volume of Raw Sludge Per Cycle + Volume of Conditioning Chemicals Required Per Cycle)

Based on this working volume, the diameter and working height of the tank should be determined. As a final step in determining the total height required for the sludge storage container, height allowances should be provided for both the top and bottom of this storage container to allow for high and low level indication as well as providing adequate freeboard to reduce potential of overfilling, excess volume for moderate and vigorous mixing, and any anticipated excess storage volume considerations.

4.2.1.3 Precoat Storage.

If required precoating of the filter media will be performed prior to the filtration cycle, a storage tank must be provided. As a general rule of thumb the tank for the precoat system should be approximately one and one-half times the volumetric capacity of the filter press.

4.2.1.4 Filter Media Wash Storage.

The size of the filter media wash tank should be based on the filter media washing requirements (duration and frequency) of the specific filter press application. The total volume required should be equal to working capacity of tank calculation described in Subsection 4.2.1.2.

4.2.1.5 Acid Wash Storage.

The size of the acid wash storage is dependent on the acid wash requirements (frequency and duration) of the specific application. The calculation of the working capacity and total size required should follow the method described in Subsection 4.2.1.2.

4.2.1.6 Sludge Cake Storage.

The size of the sludge cake storage is very application specific and will be based on the method of disposal and/or

frequency of disposal. For example for an intermittently operated filter press unit, such as a unit that is operated only once a week, only weekly up to monthly storage should be provided. However, for continuously operated filter presses, such as those performing several cycles per day, the minimum storage capacity should be determined on the basis of the daily sludge cake volume produced with additional allowances up to several days for contingencies related to transportation. Additional storage considerations are also presented in Section 4.8 of Appendix A.

4.2.2 Chemical Feed Systems.

Chemical feed systems for filter press applications may include those required for sludge conditioning, filter media precoating, and filter media acid washing.

4.2.2.1 Conditioning Chemicals Feed Systems.

The chemical feed dosages for each type of conditioning chemical required is determined from treatability studies, and are usually expressed as a percent of the sludge on a dry weight basis. Based on the mass flow rate of sludge to be generated and the percent of chemical dosage required, the chemical dosage required can be determined from the following equation:

Chemical dosage per day =
[Mass Flow Rate of Sludge (weight per day)] x
[Percent of Chemical Required Based on Sludge Dried Solids]

In addition to the determination of the daily dosage requirements, the storage requirements can be determined based on the daily dosage, concentration of chemical purity if less than 100 percent, and typical desired storage period. Typically, a 30-day storage period is required for conditioning chemical storage. The chemical feed system*s storage requirements can be calculated by the following equation:

Chemical Storage Requirement =

[(Daily Dosage) x (Storage Period)]/
[Chemical Purity]

Additional calculations are required for the condition chemical feed systems including the pure chemical feed system, chemical feed solution preparation and mixing tanks, solution metering systems. Because these requirements and related

calculations are specific to the types of conditioning chemical requirements for each filter press application, no specific calculations are provided in this appendix. However, a discussion of chemical feed systems is presented in Appendix A, Subsection 4.6.1.

4.2.2.2 Filter Media Precoat Feed System.

Precoat feed calculations required for filter press applications include those related to pure material storage and feed, precoat preparation, (tank storage), and precoat slurry feed. Because the type of precoat material and dosage required is specific to each filter press application, no specific calculations precoat material feed systems are provided in this appendix. However a discussion of precoat systems is provided in Appendix A, Subsection 4.6.2. In addition, a discussion of the calculation of precoat preparation and storage is presented in Subsection 4.2.1.3, and calculations required for pumping sizing can follow the general guidelines provided in Section 5.0 of this appendix.

4.2.2.3 Acid Filter Media Wash Systems.

The calculations required for the acid filter media wash system may include those related to the sizing the supplied acid storage tank, supplied acid feed pumps, acid wash dilution tank, and acid wash feed pumps. The specific requirements for the components of this system are dependent on the specific requirements of the filter press application (i.e., frequency and duration) in addition to the purity of the acid supplied; therefore, no specific calculation are described in this section. However, a description of design considerations for acid wash systems are provided in Appendix A, Subsection 4.6.3.2. In general, the tank calculations for this system should follow the method presented in Subsection 4.2.1.5, and the pumps calculations should follow the method presented in Section 5.0 of this appendix.

4.2.3 Additional Accessories.

Additional accessories including items such as pumps and air compressors will require design calculations. The calculations required for pumps are discussed in this appendix in Section 5.0 and air requirements and air compressors are discussed in Section 7.4.

5.0 FLOW DEPENDENT CALCULATIONS.

Flow dependent calculations are primarily required for pumps and piping distribution systems used within the filter press application. The pumps typically used in filter press applications include those required for sludge feeding,

chemical conditioning feed pump, precoat feed pump, and filter media water wash and acid wash pumps. Although different types of pumps may be required for these applications, the basic calculations performed for sizing these pumps are similar and include the determination of the volumetric capacity and pressure requirements.

The calculations for the determination of the volumetric capacity is based on the frequency, duration, and overall quantity required for each specific application. The total pressure requirement is calculated based on the total head requirements of the system that includes the summation of both the static and dynamic head characteristics of the system. An additional safety factor of 10 to 25 percent should be added to the dynamic pressure to reduce the effects caused by the thixotropic characteristics of the sludge.

6.0 EQUALIZATION REQUIREMENTS AND VARIATION ALLOWANCES.

The objective of sludge flow equalization and variation allowances is to provide sludge that contains similar characteristics for each filtration cycle.

6.1 MAXIMUM CONDITIONS.

The design and equalization requirements and variation allowance for maximum condition can be handled by several different approaches. However, these approaches are application specific and typically do not require calculations. The first method would be to size the equipment and associated system based on an average of 30 consecutive days of sustained flow and solids loading. In general, this method would cause oversizing of equipment typically required. However, if this approach involves the use of several presses to process the sludge generated at the maximum flow conditions, the number of presses operating during an average flow condition could be reduced to handle only the average flow.

A second approach that can be used consists of basing the design on the average flow of an average operating day and providing adequate storage for maximum flow conditions, then processing the additional sludge with increased operating periods. To illustrate this approach, assume the daily average flow was typically processed within an 8-hour operating period. To process the sludge during maximum flow conditions, provisions could be provided and an additional operating shift could be used to process the sludge until average conditions resumed.

6.2 MINIMUM CONDITIONS.

Although typically the design of the filter press application is based on maximum or average requirements, and no calculations are based on minimum flow conditions, consideration of the minimum flow condition is warranted. However, several possible approaches can be used to address minimum flow conditions. Potential approaches that could be applied include: providing storage until enough sludge is generated to complete average flow filtration cycle; reducing the number of filtration cycles over a typical operation period; using a blanking plate to cut down the volume of sludge being dewatered if a single filter press is being used; or cutting down on the number of units used if a multiple press system is used.

7.0 SUPPORT UTILITY REQUIREMENTS.

Based on the initial selection of equipment, utility requirements for ventilation, power, water, air, telephone, and other utilities can be calculated. Although some of these calculations may be determined as requirements for the entire treatment facility, incremental calculations may be required that apply specifically to equipment or facilities required for filter press applications.

7.1 SPECIAL VENTILATION SYSTEMS.

Typically ventilation calculations are performed with heating ventilation and air conditioning calculations for the entire treatment facility and are not specifically performed for the filter press application. Under normal conditions, as described in Subsection 9.8.2 of Appendix A, the minimum ventilation rate of six air changes per hour for summer ventilation and three air changes per hour for winter ventilation should be applied. However under specific applications, such as those in areas where dust (i.e., lime conditioning) or odor (i.e., ammonia) are possible, additional ventilation requirements and calculations may be required.

7.2 POWER REQUIREMENTS.

Several types of calculations for power requirements can be used in the design of a filter press application including a normal load and lead protection analysis, a ground fault current analysis, and lighting analysis. These types of calculations are usually performed as part of the electrical calculations provided for the entire treatment facility. Because these types of calculations are application and equipment specific only a description of these types of calculations follow.

The normal load and load protection analysis consists of the determination of electrical load requirements for the filter press and associated components such as pumps and controls. Once the load analysis is performed, a load protection analysis is then performed to ensure the proper design and placement of circuit transformers for the overcurrent protection of individual component from its power source. The ground fault current analysis is also performed to determine the rated listing for individual component.

In addition to direct power requirements, lighting calculations are typically provided with power requirement calculations. However, the lighting calculations and associated requirements are typically provided with the entire treatment facility*s general lighting calculations, unless special light requirements for platforms, mezzanines, or catwalks are required.

7.3 WATER REQUIREMENTS.

Water requirement for filter press applications include water required for fire protection and potable water. Water requirements for fire protection are typically determined by calculations required for the entire treatment facility. Potable water requirements are based on frequency, duration, and quantity required for each specific system within the filter press application. Systems that typically require potable water include: dilution water for conditioner preparation; water for precoat slurry preparation if filtrate water cannot be reused; water for the filter media water wash; and dilution water for filter media acid wash. Based on the specific requirements for each of these application, calculations will be performed for the quantity of potable water required and associated distribution systems.

7.4 AIR REQUIREMENTS.

In general, calculations for air requirements are based on the frequency, duration, quality, and pressure of air required to- perform to several functions within filter press applications including pneumatics involved in the press operation such as hydraulic press opening/closing and plate shifting, in addition to filter press accessories such as air operated pumps, core and air blowing systems, inflation systems for diaphragms for variable-volume filter press applications, and pneumatically operated controls. Typically, two types of air quality are required for filter press application: instruments air and plant air. The instrument air is typically passed through an air cooler and air dryer to produce a dry quality air required for pneumatically operated controls. Although two types of air are required, only one air compressor system is typically required to distribute the air requirements to supporting systems. Therefore calculations that are performed for the air system include those for sizing the air compressors and those for sizing air distributions systems. Because the specific calculations are equipment specific, only a description on calculations that may be required are presented in this appendix.

The air compressor system is typical sized based on the calculation of the sum of the air requirements and the highest pressure required. The air is then distributed to the air distribution system by the use of pressure regulators.

Additional calculations performed for the distribution systems include those required for sizing storage receivers air dryers, and distribution piping system. These calculations are primarily based on the specific air requirements for each individual demand.

7.5 TELEPHONE LINE REQUIREMENTS.

Design requirements for telephone lines for remote alarms are typically not performed specially for filter press applications. The specific requirements are typically determined for the site conditions and specific control outputs requiring remote alarms and specified within the guide specification interfacing with other controls requiring remote alarms within the treatment facility.

7.6 OTHER UTILITY REQUIREMENTS.

Other utilities that may be required for filter press applications include utilities such as natural gas. Natural gas may be used indirectly for filter press applications for general heating, sludge drying, and sludge incineration.

Calculations for natural gas for filter press application are primarily used in conjunction with the requirement required for the entire treatment facility. Typically, calculations that may be required for natural gas used for filter press applications include those related the determination of individual system requirements (i.e., quantity and pressure required) and sizing of the specific distribution systems.

8.0 ADDITIONAL REQUIREMENTS.

In addition to the process, mechanical, and electric calculations, additional design requirements and calculations that may be required for filter press applications include those related to architectural requirements such as the determination of aisle space, equipment clearances, and storage space; structural requirements for the filter press, supporting accessories, and chemical storage; operation and maintenance provisions; and health and safety requirements. However, these types of calculations are application specific, and therefore no specific calculations are provided in this appendix.